The Ultra Reliable Aircraft

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Abstract

Rather than a flying aircraft, the Ultra Reliable Aircraft (URA) is a research project which aims to enable substantial increases in aircraft operational availability and reliability. Customers, both civil and military, now expect reduced costs with improved satisfaction and UK industry must take action to meet these new challenges. In response, the Society of British Aerospace Companies (SBAC) through their Foresight Action programme, initiated the Ultra Reliable Aircraft programme. This programme has, as its ultimate objective, the elimination of all unscheduled aircraft maintenance. However, at the current rate of design and development effort, and in terms of reliability, attempts to dramatically increase the in-service reliability of systems and equipment are providing diminishing returns. Even when new technology and increased complexity are taken into account, what is needed is a step change in reliability performance to break the trend and realise the levels of reliability required to respond to the new challenges.

1. Introduction

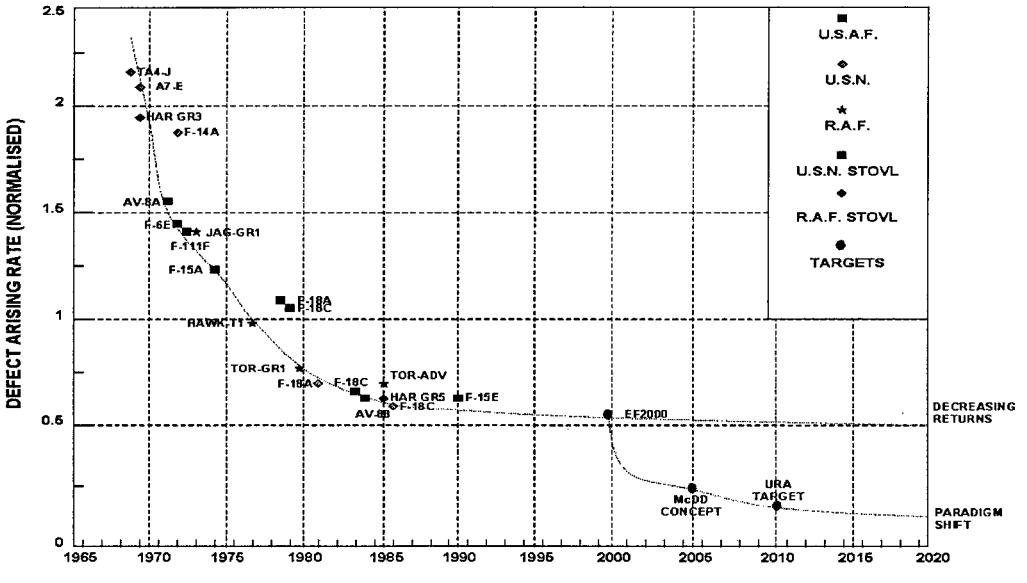
In the last ten years, the UK share of the world market for aerospace products has reduced from 13% to 9%. In the same period, competition has intensified with new entrants and existing competitors presenting new challenges. Customers expect both reduced costs and improved satisfaction and UK industry must respond to this environment and meet these new challenges. For the UK aerospace industry to maintain or increase its share of the highly competitive global market place, it must aspire to become the global benchmark for affordable Life Cycle Costs (LCC).

It is a well known fact that unscheduled maintenance disrupts the availability of aircraft and equipment, as well as producing uncertainty in the cost-effective use of assets; this has the overall effect of increasing LCC. Analysis has shown that investment in developing the processes and technologies relating to aircraft reliability will provide the greatest pay-back in terms of reducing LCC.

To a civil operator, the consequence of unscheduled delays and their rectification typically exceed £1M per aircraft per annum.
The MoD maintenance bill for its fleet is some £1B per annum.

With each new aircraft, there has been a trend towards improved reliability; this improvement has been most marked over the last 20 years. However, an extrapolation of the improvement curve shows that the gains in reliability are slowing and, if the future life cycle costs and availability targets are to be met, industry must seek ways of breaking free from the curve.

The step change required from the existing curve to a new and more aggressive curve has been called the 'paradigm shift'. The reducing returns and the paradigm shift are shown diagrammatically below:



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Within the framework of the Foresight Action programme, the Society of British Aerospace Companies (SBAC) provided the focus for such an effort through the establishment of the Ultra Reliable Aircraft (URA) industrial collaboration programme. The overall aim of the Project is the elimination of unscheduled maintenance by achieving significant improvement in the current levels of reliability. The intention is to create a market differentiator for UK companies, through the reputation of their aerospace products, in terms of dependability and reliability.

2. The Ultra Reliable Aircraft Project

The URA Project is a consortium comprising customers and platform/major systems companies representing rotorcraft, military and civil aerospace interests. The major companies are members of the SBAC; however, the Project intends to include the involvement of suppliers at all tiers of the industry to enable reliability to be addressed at all levels of the supply chain. Membership currently includes:

> British Aerospace Airbus and Military Aircraft and Aerostructures; GKN Westland Helicopters Limited; GEC Avionics; GEC Aerospace; GEC Marconi Electronic Systems; Lucas Aerospace; Messier Dowty Limited; Dowty Aerospace; Normalair Garrett; Rolls-Royce Military and Civil; BMT Reliability Consultants; The Royal Air Force; The Defence Evaluation and Research Agency and Warwick Manufacturing Group (University of Warwick).

A collaboration agreement has been signed by the partners which indicates their willingness to recognise the need to break down protectionist barriers, even between competitors; especially when each partner stands to gain from a more capable UK aerospace industry base. It was also recognised that any new processes and techniques which may be the result of work done by the partners, should be protected in terms of Intellectual Property Rights (IPR). The resultant confidentiality agreement covering IPR, and protecting information of a more sensitive nature provided by the partners, has also been signed by all participants.

3. Method of Approach

The URA has three phases: a Pilot study (which is now complete), the main Project work and a follow-on demonstration. The main Project work is about 50% complete at the time of writing this paper whilst the demonstration phase(s) are currently under discussion.

4. Pilot Phase

A partnership of companies, sufficiently concerned about their competitiveness, agreed to collaborate using £0.5M of their own funding in a one-year pilot study. This commenced in April 1996, with the objectives of:

- Demonstrating that the URA aims are sound and achievable
- Demonstrating that the disparate companies can collaborate in an open and effective manner
- Planning for the URA Project main phase
- Preparing proposals to potential funding sources
- Publicising the potential of the Project
- Recruiting further members from industry and academia.

The URA Pilot study also aimed to identify the key processes that influence reliability. In order to achieve a significant improvement, it will be necessary to adopt new processes, develop new technologies and change the cultural attitude to reliability engineering.

5. URA Main Phase

Following the Pilot study, the main Project phase commenced in April 1997 and is being funded jointly by industry, the MoD and the DTI. The aim is to further develop the modelling, best practice and technology themes to a point where they can be applied to existing or emerging technology demonstrator programmes. A key aim is to identify the areas that will produce the greatest dividend in improved reliability.

5.1 Work Programme and Breakdown

The URA aims to achieve its challenging target through a programme of six Work Packages. Each work package has a lead partner and contains several sub-tasks. The first five packages have the following aims:

> **Work Package 1** - Identify the feasibility of achieving the complete removal of unscheduled maintenance and the provision of "guaranteed" Maintenance Free Operating Periods (MFOPs)
>
> **Work Package 2** - Identify and develop the world best practice 'Design for Reliability' and producing a 'Best Practice Handbook'

Work Package 3 - Demonstrate the benefits to aircraft operators through simulation of LCC reductions and the commercial benefit to industry through new operating procedures

Work Package 4 - Network existing technology programmes and identifying and developing technologies to support the target goals

Work Package 5 - Benchmark the URA partners against their competitors.

The sixth work package (Work Package 6) provides the overall co-ordination of the Project.

Each work package is more fully explained below and Appendix A details the objectives and task descriptions, along with the partners leading and/or participating in each.

1.1.1. WP1 Paradigm Development

This work package consists of studies into various support and procurement policies for aerospace products. It is evaluating alternative strategies and will determine the consequences, both technical and commercial, for suppliers and the operators. It involves the consideration of novel approaches to failure forecasting, condition monitoring and fault tolerance provision, as well as the contractual terms that might be invoked for performance warranties. The aim of the work is to identify a paradigm capable of the elimination of unscheduled maintenance and the provision of "guaranteed" MFOPs. In addition, this work package will include academic contributions to the other work packages below.

1.1.2. WP2 Process Group

The guiding principle for the process group is the perception that business engineering and manufacturing processes are the key factors in facilitating the production of reliable products. The URA Pilot activities led to identification of the sensitive processes and to their ranking, according to their impact on reliability.

The Process Group is developing a set of recommended processes, taking the best elements from any relevant sources, to produce a compendium of best practice guidelines for incorporation into the business procedures of the URA partner companies. The best practice guidelines are being developed from the practices in use in aerospace and from other industry sectors world wide. The task will involve literature searches, working parties and visits to partner companies, to review current practices and document the findings. The approach is using case studies taken from the partners and the study of how other companies improve their processes. Within Work Package 3 described below, the reliability impact of applying best practice is being assessed and compared with current performance. In addition, a set of selected processes for design, development, qualification and manufacture are being simulated in a synthetic environment model.

There is recognition that a more cross company participative culture is needed to address reliability, involving all levels of the supply chain. For example, involvement of participants from all levels of the supply chain will lead to improved project communication, design specifications and the more effective co-ordination of production quality. The relationships between suppliers at different levels in the supply chain, and between those at a similar level, whose products must integrate together are being studied. Recommendations will be made for preferred supplier arrangements and concurrent engineering practices, as they relate to the achievement of dependable and reliable products.

Tools and methods are being identified that will assist in the business, engineering and manufacturing process, including the collection of failure reports (both for products and processes), root cause analysis, collation of information on reliability databases, the best ways of assessing reliability, the best practice use of reliability procedures and lessons learned databases.

1.1.3. WP3 Modelling Group

In the URA Pilot Phase, the root causes of unreliability were investigated, using a causal tree model, populated with data from the records of existing projects covering each main sector of aerospace products. This was used to rank the drivers for the process and technology assessment main phase work. The impact of reliability on LCC was evaluated for some simple cases and this is being extended to a full study in the URA Main Phase. In order to work with contracts stipulating MFOP warranties, it will be essential to have a capability to credibly forecast the reliability performance of systems and aircraft in MFOP terms. This will require simulations designed to track a large number of individual lifed items for each aircraft and its systems, and to add in the effects of functional redundancy and carried faults. The failure statistics and characteristics of lifed items are being explored, to see if the variability between individual examples of components, and their usage, is small enough to allow meaningful predictions to be made. Reliability data for input to LCC models has been traditionally derived from "random failure" Mean Time Between Failure (MTBF) handbooks and company databases, which reflect existing products. A new style database will

be needed for the assessment of future products based on the above MFOP principles. This database format is being generated together with the Technology Assessment group, to form an industry generic tool for reliability assessment.

A synthetic environment modelling exercise is being used to assess the impact of process improvements and novel technologies on the operational capabilities, costs and support levels needed, from the operators' viewpoint. This addresses operational readiness, availability, flexibility of deployment, attrition rate due to failures, mission success rates etc., for the military, and will review despatch reliability, Aircraft On Ground (AOG) provisions and support logistics for civil users.

1.1.4. WP4 Technology Assessment

Technological improvements can make substantial contributions to the reliability and dependability of aerospace products, not only in the fields of components, processes and materials, but also in the disciplines of systems architectures, diagnostics and fault tolerance. A major concern of all aerospace operators is the very high level of No-Fault-Found (NFF) removals, which greatly detracts from availability and adds to costs. The self diagnostic capabilities of equipment need to be greatly enhanced, by improvements in detection, location and false alarm rates. Available NFF data is being reviewed to identify root causes, both technically and organisationally. Current advances in diagnostics are being researched and recommendations made for reinforcement where shortfalls are identified. Operators and maintainers are being interviewed to further establish the underlying problems and their causes. Health and condition monitoring provides another avenue for improved dependability and the present capabilities will be established as the basis for recommendations for further developments. The current status of vibration spectral analysis, performance trend tracking, temperature profiles etc., is being reviewed and suggestions made for further improvement.

In order to assess the improvements likely to made by the introduction of specific elements of technology, a "tool" is being developed for use within the group, capable of:

- Co-ordinating the outputs of case studies, technology investigations and databases
- Collating information from existing reliability databases
- Listing relevant bibliographical references
- Running case studies into the consequences of technology insertion.

Within the participating companies, research institutions and academia, there are technology improvement programmes that will bring benefit to the reliability of aerospace products. The Technology Assessment group is considering how these can be networked to provide overall aircraft reliability improvements. From the Process and Modelling groups, the most significant and effective areas for realising improvements will have been identified. Where these are already being addressed within identified technology programmes, the URA will seek to establish links and monitor progress. Where there are technology gaps, not being addressed in such programmes, the Technology Assessment group are making recommendations for additional activities to complete the technology coverage.

1.1.5. WP5 Competitive Analysis

In order to track the benefit of the URA to the UK aerospace industries, a benchmarking exercise is being carried out, researching the capabilities of overseas infrastructures, their improvement status and rate of uptake of novel processes and technologies. The URA recommended practices will be compared with the international trends and any potential UK advantage(s) derived. Individual participating companies, within the URA, will be encouraged to align themselves to the benchmarks and then to evaluate their level of uptake of the potential URA benefits.

1.1.6. WP6 Project Management

The definition, process, modelling, technology assessment and simulation Work Packages are programme managed through a formal project management team, agreed by the consortium.

6. URA Demonstration

On completion of the technology assessment (WP4), a report will be produced recommending the process and technology demonstrations that would be required to progress towards the overall aim of eliminating unscheduled maintenance. These recommendations will place identified existing programmes in their reliability context and will advise where new programmes are desirable. Where a need to develop innovative technologies or processes is identified, recommendations for supportive projects will be formulated.